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Electronics Industry Study Report: Semiconductors As Proxy

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Electronics

ABSTRACT: The U.S. Government in general and the Department of Defense in particular represent such a small portion of the electronics industry's business that without a significant change in policy and approach, equipment vital to our national security may not be readily available. Using the semiconductor industry as a proxy for the sector, this study suggests ways the U.S. can leverage the healthy (and bolster the flagging) portions of the commercial electronics sector to ensure ready access to strategic items that will be required to provide the capabilities necessary to meet rapidly changing threats in a global environment.

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PLACES VISITED:

Domestic:
AAI, Hunt Valley, MD
Alien Technology, Mountain View, CA
AMD, Sunnyvale, CA
Lockheed Martin Corporation, Arlington, VA
LSI, Milpitas, CA
Rainbow Project, Lockheed Martin Corporation, Oakton, VA
National Security Agency, Ft. Meade, MD
Naval Postgraduate School, Monterey, CA
Northrup Grumman Electronics Sensors and Systems, Baltimore, MD
Northrup Grumman Electron Devices, San Carlos, CA
Palm, Inc., Santa Clara, CA
Sentir Semiconductor, Inc., Santa Clara, CA
Semiconductor Industry Association, San Jose, CA
Solectron, Milpitas, CA
Virginia Semiconductor, Fredricksburg, VA
Xilinx, San Jose, CA

International:
601st Communications Group, Argentine Army,
Autotrol, Buenos Aires, Argentina
Centro Técnico Aeroespacial, São Jose dos Campos, Brazil
Embraer, São Jose dos Campos, Brazil
GE Celma, Petropolis, Brazil
Lockheed Martin Aircraft Argentina S.A., Córdoba, Argentina
Motorola Argentina S.A., Córdoba, Argentina
Petropolis-Tecnopolis, Petropolis, Brazil
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Siemens, São Paolo, Brazil
United States Commercial Service, São Paolo, Brazil
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INTRODUCTION:

The purpose of this study is four-fold. First, it provides a brief summary of the current state of the U.S. electronics industry. Second, it provides a short description of the challenges facing this industrial sector. Third, it discusses what we believe will be the future trends in the industry, and fourth, it presents what we believe are the necessary actions required by the U.S government to ensure this sector continues to support national security requirements.

In order to prevent the dilution of this survey that would occur if we tried to cover the plethora of industries comprising the electronics industry, our study group found a proxy industry, semiconductor device (SCD) design and manufacture. The health of this industry serves well as a barometer for all the remaining industries in the electronics sector since all of them require some form of SCD. We combined elements of the Classical, Technology, and Industrial Competitive Advantage industry analysis approaches to examine the design and manufacture of SCDs, and then validated our findings from this proxy industry in a select number of other electronics industries.

The focus of our study was the national security and global economic (and strategic) implications of the semiconductor industry's health as it relates to supporting U.S. defense mobilization and readiness. What is presented here is our executive summary of what is today, what may be tomorrow, and what needs to be done in the electronics industry to ensure a continued contribution to the U.S. government's constitutional requirement to provide for the common defense.

THE INDUSTRY DEFINED:

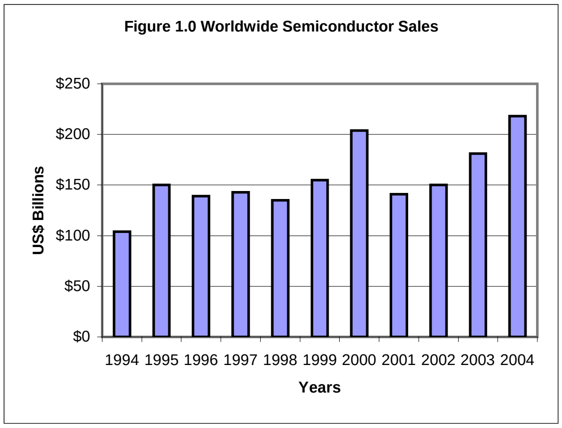
Using SCD design and manufacturing as a proxy industry simplifies immensely the scope of a study of the electronics industrial sector. The need for such a proxy arises from the ubiquitous nature of the electronics sector. "Electronics" span all other industrial sectors, from household appliances to children's toys to modern transportation and communications industry. In almost every manufactured object today, some form of SCD is used either as a component of the object or at some stage in its production. Without the input from a healthy SCD sector, most other industries would suffer. Therefore, the SCD sector forms a cornerstone of modern industrial growth.

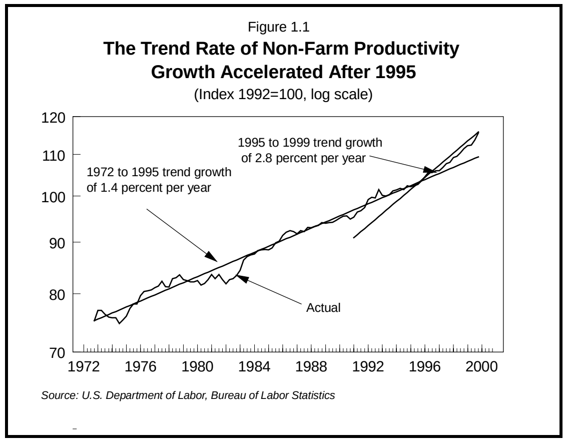
We define the SCD sector as that portion of the industry that designs, manufactures and assembles "microchips" either as discrete components (pressure and light sensors for example) or as part of an integrated assembly (Field Programmable Gate Arrays, computer microprocessors, or Application Specific Integrated Circuits (ASICs) for example.) We looked at a full spectrum of players in the SCD sector, from those who produce silicon substrates, to those which are heavily vertically integrated, doing all design and fabrication of devices all the way to those that perform design services and contract out fabrication (known as "fabless"). We found that despite a recent significant economic downturn in this sector, the industry remains healthy and still has tremendous growth potential. However, because of the huge demand for SCDs across so wide a range of industries, the portion of the market that is represented by government and Department of Defense (DoD) is infinitesimally small when compared with the commercial market. This represents a serious challenge to the U.S. government with respect to its ability to satisfy national security requirements. Gone are the days when DoD drove the market. And only now is the DoD waking up to this fact.

CURRENT CONDITION:

Trends in worldwide semiconductor and microelectronics trade:

Worldwide trade in semiconductors is temporarily down approximately 30% from its $204 Billion year high in 2000. Industry experts cite several reasons for the recent downturn: (1) general economic slowdown, (2) dramatic slowdown in the telecommunications boom, (3) dot.com meltdown, and (4) glut of microelectronics inventory. The events of September 11th, 2001 only exacerbated the downturn and perhaps slowed the recovery in the semiconductor market.





Trends in consumer and business electronics overwhelm any trends in U.S. defense electronics. Ironically, as electronics become an integral and larger portion of advanced weapon systems (greater than 20% of an average weapon system), the defense electronics industry is a shrinking portion (< 1%) of the overall microelectronics industry. Following September 11, 2001, the U.S. defense budget for fiscal year 2002, increased substantially. However, in the next decade, the defense budget will grow a modest 1.4% (above inflation) compounded annually. The defense electronics component of the national security budget should grow somewhat faster—about 2.1% a year.[1] Nonetheless, defense electronics is still almost irrelevant to the burgeoning electronics industry.

Electronics Industry Productivity. As shown in Figure 1.1, non-farm economic growth rate doubled from a sluggish 1.4 percent rate between 1973 and 1995 to a 2.8 percent rate from 1995 to 1999.[2] Interestingly, for the last quarter of 2001, non-farm productivity accelerated at a robust 3.5% annual rate. This indication gives relevance to the possibility that as high tech electronics technology development (hardware, software, and connectivity) continues to accelerate, it may be playing a more across-the-board role in producing overall economic growth. This productivity trend invariably enhances U.S. electronics industry's competitiveness.

Electronics Industry Competitiveness. The U.S. electronics industry's competitive advantage is creativity, flexibility, connection to intellectual markets (Universities, R&D activities) and capital markets. The U.S. industry tends to create, design, and develop the leading edge electronic based capabilities, including the necessary automated manufacturing equipment. Thus, the U.S. electronics industry remains competitive in the global marketplace. However, the U.S. fabrication of SCDs has declined significantly, from approximately three quarters of the world supply in the 1970's to an estimated 20

percent in 2004. In the continually growing electronics industry, the fabless sector is growing the fastest. In the 1970's the U.S. was by far the leading provider of the world's semiconductors. Today, indeed, 70% of all semiconductors now come from overseas. In the 80's and 90's, U.S. semiconductor manufactures sought trade protection and quotas to limit the higher quality and lower price imports from Japan. Now the largest providers are in Taiwan and Korea. Today, the call for protectionist measures has subsided. Finally, the U.S. electronics industry appears to understand its competitive advantage--high value added activities (i.e. design and development of electronics) are more profitable than fabrication. The expected return on investments is 60%[3].

CHALLENGES:

The leadership of the companies we visited expressed a wide variety of concerns relating to the continued competitiveness of their firms. Additional research confirmed that there are a number of challenges that must be addressed if U.S. electronics industry is to maintain its technological and economic dominance. Some of these challenges could have a direct impact on U.S. military readiness and national security. While certainly not all inclusive, some of the most prominent challenges are discussed below.

Technological Challenges. In microprocessor semiconductor technology, the quantity of transistors able to fit on a given area of silicon appears to be doubling every 18 months.[4] The ability to fit more transistors on the same chip has greatly increased processing speeds and drastically reduced the per-transistor cost of manufacturing of electronic devices; however, there are significant technological challenges to overcome because as devices get smaller the laws of physics are pushed to their limit. Overcoming the obstacles in device, circuit and chip design and manufacturing requires a substantial investment in fundamental research and development (particularly in material science and process engineering) and an extremely well educated work force.

High Tech Workforce. Numerous companies we visited expressed concern about the ability to hire and retain workers with adequate technical skills. According to the Semiconductor Industry Association (SIA), U.S. chipmakers will require over 15,000 new electrical engineers (EE) in the early years of this century, yet EE graduates declined by 49% from 1988 to 1998, along with decreases in other important disciplines such as math and physics.[5] In addition, the SIA notes that federal funding for university-based education and research for engineering has dropped by 30-40%, funding for math and physics has dropped by 20%, and funding for chemistry has dropped by 10%.[6] Given the increasing cost of high technology training, loss of funding (and other factors) will result in a continued shortage of degreed personnel in the fields most needed by the industry. Additionally, the majority of those completing degrees are foreign nationals, which creates a problem for national security related work as granting of both security clearances and H1B work visas for these individuals has become increasingly difficult in the post 9/11 world.

Escalating Manufacturing Costs. Joint ventures, outsourcing and other efficiencies are not new phenomena to this industry, but there is ample evidence that trends are accelerating. Cash strapped companies usually find it hard to make capital expenditures during the downturn of a cycle. What is different this time around is the rapidly accelerating cost of new fab facilities. Current estimates call for an investment of

$3 billion for a new 300mm fab today.[7] And the leading-edge semiconductor production equipment will have a life expectancy of as little as three years. In order to remain competitive, companies must find ways to tap into the latest wafer size and line width production technology. However, because "[t]he hard cost and opportunity costs are not offset by a return on investment, unless you can justify it through volume or differentiating technology"[8] many companies are reluctant to make large capital investments. The obvious answer for those companies that realize they can not afford the investment today, or certainly will not be able to afford it tomorrow, is to seek out partnerships with foundries that can produce with the latest technology, or to simply outsource part or all of the production effort. According to the Fabless Semiconductor Association, "the fabless segment comprises 13 percent of the worldwide semiconductor industry,"[9] and the association believes that 50 percent of all integrated circuit revenue will come from fabless operations by 2010.[10]

Moving Offshore. Where are fabless companies taking their business? Seventy-eight percent are going to the world's top three foundries: Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC) in Taiwan, and Chartered in Singapore. According to the Fabless Semiconductor Association, these three companies alone represent 37 percent of world foundry capacity, and almost 60 percent of their business was from U.S. companies in 2001.[11] When combined with China, south Asia accounts for 50 percent of foundry capacity. Consolidation of foundry work in South Asia will likely continue, facilitated by elimination of trade barriers, protection of intellectual property rights, and boosted by more companies outsourcing their production. China also appears to be a big growth market for foundries, as China has signed the Information Technology Agreement and is joining the WTO. Taiwan recently lifted export restrictions on current 200mm wafer investments, opening the door for TSMC and UMC to build additional foundries in China.[12] These actions will lead to a less diversified source of supply, leaving U.S. companies vulnerable to impacts from any disruption in the global supply chain.

U.S. Export Controls. U.S. government policymakers face tough choices in balancing national security interests with commercial industry's desire for export sales. A number of companies we visited expressed concern that current export controls placed them at a disadvantage in the global marketplace because the type of technology that is restricted is readily available from other foreign sources. In addition, the SIA believes that chips alone do not determine superior military capability. Instead, military superiority is achieved through extensive engineering required to integrate chips into military applications. They believe that software and system design capabilities are the key to national security considerations, not the chips themselves.[13] This thinking was collaborated in our review of the industry. A more rational and realistic approach may be needed if U.S. companies are to remain competitive in the global market.

Negligible Defense Influence. The Defense Department's influence over the U.S. electronics industry has declined dramatically since the 1960's, when the military and the space program were the dominant consumers of semiconductor components. The predominant market today is for commercial and consumer applications. While military requirements continued to drive cutting edge research and development into the 1970's, defense purchases of the semiconductor industry's output dropped to 35 percent. The declining trend continued to 7 percent in 1984 and to less than 1 percent today.[14] Some

estimates go as low as 0.03 percent.[15] Most of the major chip producers have long since left the military market, leaving defense with few suppliers - a situation referred to as Diminishing Manufacturing Sources (DMS).

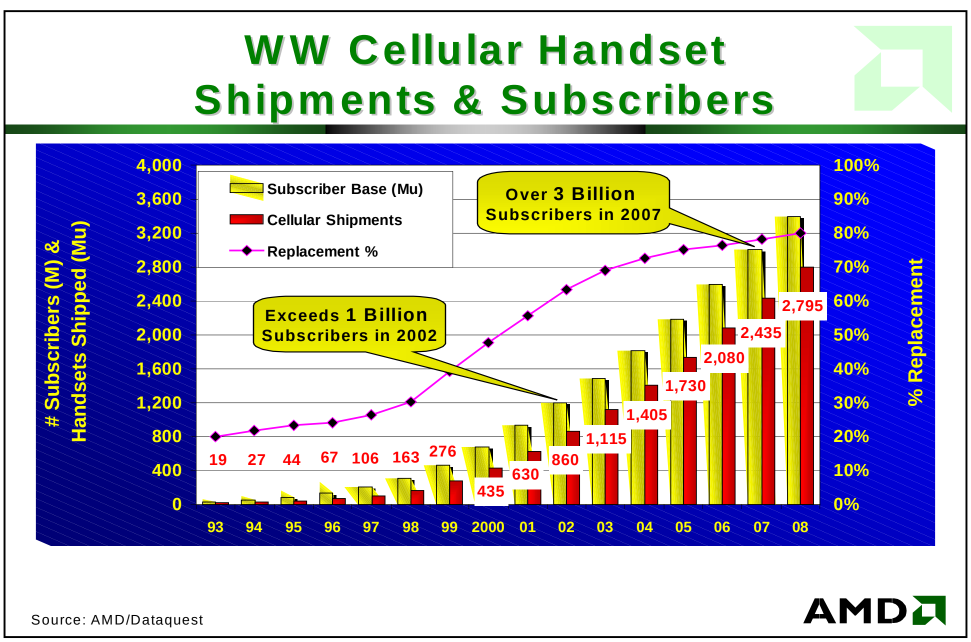
Even when defense contractors are able to find commercial electronics components that can be integrated into weapon systems, they can find themselves at the back of the line when it comes to procurement and delivery because of the small quantities they require. During the height of the "dot com" boom, some commercial component suppliers would not even take orders from defense contractors when they had difficulty meeting high volume commercial customers' orders. Some defense contractors were reduced to buying cell phones in order to take them apart for components they could not buy.[16]

If one makes the assumption that the electronics industry is a key driver behind military technological capabilities, just as it is in the commercial sector, then there is cause for concern. If the Defense Department is going to be truly successful in its transformation efforts, there will have to be a reallocation of national resources sufficient to induce the electronics industry to shift its attention to the military market.

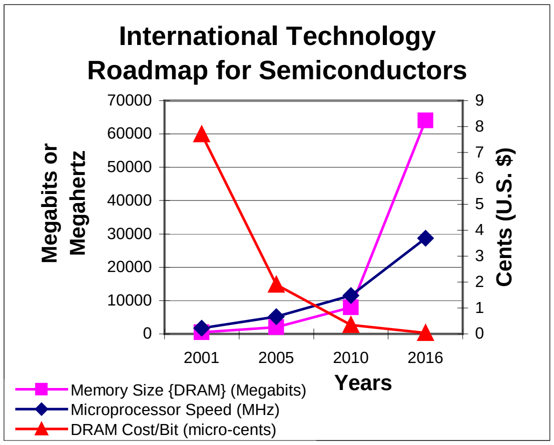
None of these challenges are insurmountable. They do require, however, attention from both the industry and the government to ensure they are addressed. Only through this due diligence will the U.S. SCD industry remain globally dominant, enabling its growth while providing what is necessary to support national security interests.

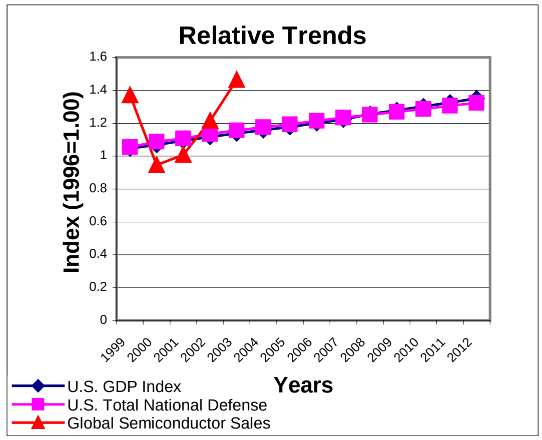
OUTLOOK:

The most significant influence affecting the industry is the economic and technological trends.[17] In a rising economy, the demand for electronics grows, and in a declining economy demand wanes. The demand for electronic end products such as cell phones, Internet computing devices, digital cameras, wireless appliances, and others, drive the semiconductor boom and bust cycles. The next figure graphically depicts worldwide cellar phone demand (WW Handset Shipment and Subscribers); it highlights the enormous growth over time.



The pace of "electronics" miniaturization, and its further infiltration into our lives, will continue to accelerate. Today, semiconductor manufactures can fit electronic circuitry, comparable to the detail of a street map of New York City, on the head of a pin. The "International Technology Roadmap" figure below shows that the semiconductor memory size and speed will increase substantially and the cost per megabit will decrease from 8 cents in 2001 to 0.42 cents in 2016.[18] while such trends have been a clear boon to users, they also make it difficult for producers to remain profitable.





SHORT-TERM FORECAST[19]

Economic Recovery in 2002 and 2003: Improving. With consumer spending accounting for 2/3 of U.S. economy, consumer confidence will remain the principal force driving the short-term forecast for electronics. Some early successes in the war on terrorism seems to be boosting U.S. consumer confidence, which bodes well for the economy and semiconductors. Current leading consumer end products include cell phones and computer games.[20] Also affecting the demand for semiconductors and electronics are a number of second order factors, some outlined next:

- **Business Transitions: Improving.** Continued changes in business patterns promote new corporate IT spending as do new security risks.
- **High Technology Equipment Market: Improving.** The equipment market should recover throughout 2002.[21] The chip makers want to continue to further reduce total manufacturing costs and need to invest in fabrication and tooling necessary to go from the current generation 130 nanometer (nm) to the next generation 90 and 65 nm.

LONG-TERM FORECAST:

Some of the factors influencing the short-term will continue to influence the industry in the long-term. For example, technology change will continue to accelerate, including performance and capability advancements in wired and wireless communication products. Also, the transition from analog to digital applications will continue, increasing semiconductor content in household appliances and other consumer products. Bottom line: For the foreseeable future, GDP growth and the resultant consumer demand for electronic end products will continue to have a dominating effect on the semiconductor industry. In general, semiconductor (and therefore electronics)

growth will exceed both the U.S. GDP and National Security budget growth, as shown in the "Relative Trends" above.

Attracting and retaining talented high technology employees will be a challenge. According to the Bureau of Labor Statistics, high tech electronics manufacturing and services accounted for 5.3 million jobs in the year 2000. This is comparable to the same level of employment sustained in the food, chemical and automobile industries combined. Comparing high-tech employment statistics from 1994 through 2000, there has been an increase of 38% in high tech jobs. However, there has been a 23% decrease in computer science degrees awarded between 1983 and 1987 while there has been a 300% increase in the number of computer specialists employed during the same period. From 1995 through 2000 there was also a 4% decline in engineering degrees across the board, however, computer and bioengineering degrees were up 68% and 34% respectively following the explosive growth and opportunity available towards the later part of the 1990's.[22] The success of the industry is closely dependent on our nation's ability to grow the human capital it needs to stay on the leading edge. Our school systems are struggling to keep up with change, and they need additional resources to meet future industrial expectations. Until our schools can catch up, we must support industry efforts to import talent from around the globe. By supporting industry efforts to transform education and attract the necessary talent, we will ensure ourselves a renewable world-class workforce that has no peer, continued dominance in the global technology arena and unprecedented prosperity for decades to come.

ASSESSMENT:

Indeed, U.S. dependence on semiconductors and electronics will only continue to grow with more and more products being manufactured overseas. Despite our growing dependence on semiconductors, there does not appear to be substantial evidence of a significant security risk. Consequently, *the U.S. government should not try to subsidize this industry merely to support the DoD*. Also given the pace of technological change and capital requirements, the government should let market forces keep the industry fit. For example, industry experts predict a future semiconductor foundry (with operational lifespan of only 5-10 years) will cost at least $10 billion in 2010.[23] And it is hard to conceive of U.S. interagency and legislative processes producing better and more feasible policies without strong intervention and leadership from the President. Alternatively, *the U.S. electronics industry and government should nurture and encourage the industry's competitive advantages* such as R&D leadership, leading edge development, innovativeness, flexibility, market prowess, and capital robustness. Such an approach would benefit the entire industry, one composed of a diverse range of large, mid, and small sized technology companies.

Electronics and software are becoming an increasingly larger and more integral portion of military weapon systems. Paradoxically, the U.S. government, (and more specifically the DoD) influence over the industry will continue to decline. The continuing challenge for the DoD: *Pursue better approaches to capitalize commercial technology advancements and appropriately ensure the health of its defense electronics industry providers.*

These recommendations are discussed in more detail in the following section and in the individual essays provided as a part of the report.

GOVERNMENT GOALS AND ROLES:

The semiconductor industry is a major driving force for the electronics industrial sector. It is at the core of the information technology explosion of the 1990s and is the bedrock of America's largest manufacturing industry (electronics, at $200 billion). Like all other US industrial sectors, it is subject to government regulation and oversight. Frequently, industrialists' desires conflict with federal policies. In general, they believe government regulation causes them to lose foreign sales due to overly strict export control laws that inhibit free and open trade. They are concerned that encryption restrictions limit the growth of e-commerce, that intellectual property protections must be more rigorously enforced internationally, and that immigration and taxation policies must be balanced to support an internationally competitive industrial sector. Ultimately, industrialists believe that a healthy and vibrant US economy is the strategic basis of national security. This view is contrasted against the federal government's desire to insure US national security through controlling the transfer of sensitive technologies to foreign nations, insuring difficult to break encryption technologies are strictly controlled, and seeking strict compliance with U.S. immigration law and tax policies by all.

The most significant risk to the U.S. semiconductor industry is the potentially fragile global supply chain. Disruption of the chain, for whatever reason, could leave U.S. industries "high and dry". Coincidentally, the defense share of the semiconductor sector continues to decline (less than 1% of the market). As such, government involvement in this industrial sector is generally viewed as obstructionist at best, and anti-business at worst. Additionally, more open global markets increase the trend of producing overseas as producers seek efficiencies through cheaper or more productive labor markets.

The primary reason for US Government controls and restrictions on high technology exports is to deny access to those who would seek to use such technology against the US—specifically, rogue nations and terrorist organizations. A subordinate rationale is to maintain the US military technological advantage. While electronics industry trade associations generally support the goals of export controls, they remain highly critical of export control implementation as they impose barriers to entry into foreign markets and stifle competition. For instance, the Semiconductor Industry Association (SIA) believes "export controls should be imposed only when they are necessary for national security, capable of being effective, and nondiscriminatory against U.S. exporters."[24] SIA maintains that semiconductors are a global product, manufactured and sold worldwide. As a result, many of the semiconductors the US seeks to control are often available on the world market from foreign semiconductor manufacturers. Given the international availability of semiconductors, SIA does not believe semiconductors are "either worthy of or susceptible to export controls." Further, SIA argues "controls on such products stifle US technology leadership and cede competitive advantage to foreign competitors without achieving any apparent national security benefits."[25] Our study found that, across the industry, there were technologies and components available elsewhere in the world that U.S. companies were prohibited by regulation to export. Thus, our study supports the SIA's position that semiconductor devices as end items are overly regulated and that new standards need to be applied for controlling sensitive exports.

Our study group found that evidence that strong encryption will be the key to the future stability of global electronic communications and commerce. While US firms are world leaders in encryption technology, export restrictions inhibit them from freely exploiting all markets. The US Government restricts US companies from exporting strong encryption software for two reasons: law enforcement and national security. The government wants the ability to eavesdrop on electronic data communications of criminals and terrorists in order to prevent criminal acts and prevent terrorist attacks. The SIA, on the other hand, views US encryption export controls as being unduly burdensome and imposing unnecessary restrictions on US exporters. The SIA argues that in terms of availability on the world market, semiconductors and strong encryption software are similar, i.e., they both are readily available on the open market from foreign competitors--stated simply, the genie is already out of the bottle.

The Information Technology Industry Council (ITIC) views four areas as being key to ensuring free and open trade: (1) tariffs and non-tariff barriers; (2) governmental commitments on the treatment of information technology (IT) services that enable e-commerce; (3) Trade-Related Aspects of Intellectual Property Protection (TRIPS); and (4) e-commerce.[26] The ITIC advocates eliminating or phasing out any tariff or non-tariff barrier applied to information technology, and obtaining commitments from foreign governmental entities to liberalize trade (i.e., avoid anti-competitive behavior) in those IT services necessary for e-commerce. Additionally, the ITIC calls for strong protection of intellectual property in accordance with the World Trade Organization's (WTO) TRIPS agreement, and for the application of WTO rules and obligations to e-commerce transactions. In each area enumerated, the federal government's position on trade competition is similar to the ITIC; therefore, the US Government can play an important role in shaping the international trade environment and thereby promote and encourage free and open trade.

Protection of intellectual property has become a major issue for the electronics industry, and this is especially true in the semiconductor sector, where US companies are the acknowledged world leaders in chip design. To recoup their investment, US firms must have government assistance in protecting their intellectual property. Domestically, US patent and copyright laws afford this protection. Overseas, however, product piracy is still a big problem. The US government's role is to keep domestic laws up-to-date with the pace of technological advancement and to obtain and enforce international agreements (1) prohibiting piracy and (2) respecting intellectual property rights.

US semiconductor manufacturers contend it takes too long to re-capitalize huge investments under the current tax structure. The SIA points out that US tax law allows companies to depreciate semiconductor manufacturing equipment over five years (instead of the three-year economic life-cycle of microcircuit manufacturing equipment). By contrast, Japanese tax law allows a company to depreciate up to 88% of semiconductor production equipment during the first year.[27] US industrialists maintain that US tax law must be updated to reflect "the rate of technological obsolescence of chip manufacturing equipment if the US is to be considered an attractive investment location."[28]

Other areas where US tax policy impacts the electronics industry are the R&D tax credit and Internet taxation. The American Electronics Association (AEA) advocates, with some modifications, a permanent R&D tax credit instead of the temporary tax credit now on the books until 2004.[29] If the credit were permanent, companies would have

more certainty and would be better able to plan their R&D investments. The AEA also supports the moratorium on Internet taxation.[30] The AEA believes that Internet commerce is in its infancy and uncontrolled taxation by over 30,000 taxing jurisdictions will strangle the growth of e-commerce. The AEA calls for Internet tax simplification, with both Congress and state legislatures playing a role. In the face of projected deficits, there is not a large ground swell of congressional support to provide any specific tax relief to the electronics industry. Thus, the electronics industry will continue to view US tax policy as disadvantageous.

The industry interest in immigration is largely a workforce issue. Due to a US shortage of high tech workers, the industry seeks to make up the difference through the H1-B visa program. Under the program, up to 115,000 skilled, foreign workers could enter the US to work for high tech companies. However, with US unemployment rising and concerns about terrorism in the aftermath of September 11th, immigration policy is undergoing greater and more intense scrutiny. Many in Congress advocate reducing the number of visas issued under the H1-B program. This is another area where the industry's economic interests may take a backseat to national security interests.

"We're either sipping champagne or stomping grapes. There's nothing in between,"[31] remarked one industry participant concerning the semiconductor industry. His comment aptly describes the cyclical nature of the business. Since 1971, the industry has experienced no less than six up and down cycles. In virtually every instance, the downturn has been attributed to excess inventory. Rapidly increasing costs to bring a chip to market, as well as the huge capital expenditures to build and equip production facilities that produce the latest technology, result in a race to be the first to market in order to establish market share and recoup costs. In the latest downturn, excess inventory was estimated at $3.9 billion by the end of 2001, down from $15 billion one year earlier. Inventory should decrease to $1.8 billion by the end of March, and disappear by the end of the second quarter.[32]

As noted earlier, the DoD presence in the electronics has diminished so much as to relegate it to almost "special niche" status. The declining trend reflects continued defense requirements for unique, military specification chips while the overall market has become driven by consumer product demands. Most chip producers have long since left the military market, leaving defense with few suppliers and little leverage over the semiconductor industry.

The U.S. Defense Department still maintains a modest research and development effort, attempting to use what little leverage they have to solve some of the unique challenges and requirements that face military system builders. For example, DoD recently awarded a number of research contracts to universities, several directly targeted at semiconductor issues. The average contract, though, amounts to only $291,000 – hardly the kind of effort that can be expected to produce major breakthroughs which in the past of cost millions.[33]

INDUSTRY STUDY CONCLUSIONS:

The United States' military power is crucial to attaining its goals in world affairs. Increasingly, the military relies on high technology electronic equipment to get the job done. In fact, electronic content now takes up almost half of all money available for DoD procurement and R&D.[34] While electronics spending dominates defense revenues, the

gargantuan commercial electronics sector dwarfs the defense electronic industry. As noted earlier, the defense market only makes up less than 1 percent of the market today falling from its pre-eminent 35 percent position in the 1970s.[35] This smaller defense market presence coupled with the global nature of the industry presents many challenges for the US defense electronics producers as they attempt to meet the nations needs.

Electronics affect our lives at every turn. Electronic components and technologies are integral in every product and process from talking toys to supermarket checkouts to the digital watches on our wrist. The industry is a behemoth with over $3 trillion in revenue for the Electronic Business 300 alone.[36] It employs 5.3 million people in the US. This is more than the food, chemical, and auto industries combined. High technology merchandise accounts for 29 percent of US exports. At $223 billion, this is double the dollar value of transportation exports, the next largest segment. [37] These statistics indicate both the importance of the industry to US economic health and the industry's global nature.

The defense electronic industry is an integral and expanding source of US military strength and, therefore, is a key element of US national power. As the commercial sector exploded and defense budgets dropped, the defense electronic industry shrank to a very small portion of the overall electronics market. The astronomical developmental and production costs of cutting edge component technologies compel low volume defense electronics firms to follow the technical lead of their commercial brethren.

The fact that the large businesses are unwilling to take on the limited production runs required for DoD specialized electronics needs should be a wake-up call for the Department of Defense. The continued consolidation of the defense industrial base in an "acquire or be acquired" fashion only makes these large defense contractors more like their commercial brethren. To 1) overcome critical shortages and hence long lead times of relatively simple military specific parts, 2) provide sufficient component production capacity to support current DoD needs for both legacy and new systems, and 3) provide a surge capacity for future requirements 4) and ensure US leadership in the next generation technologies, the DoD must invest to some degree in every link of the product's supply chain from research and development through sustainment of fielded systems. Special emphasis and investment must be applied to those portions of the supply chain that are most constrained and uncertain. While the DoD must provide necessary, sufficient and affordable incentives, it should not try to subsidize this industry. Also, given the pace of technological change and capital requirements, the government should let market forces keep the industry fit. For example, industry experts predict a future semiconductor foundry (with operational lifespan of only 5-10 years) will cost at least $10 billion in 2010.[38] And it is hard to conceive of a U.S. interagency and legislative process that would produce a better and more feasible implementation. Alternatively, *the U.S. electronics industry and government should nurture and encourage its competitive advantages* such as R&D leadership, leading edge development, innovativeness, flexibility, market prowess, and capital robustness. Such an approach would benefit the entire industry that is composed of a diverse range of large, mid, and small sized technology companies.

Similarly, electronics and software will become an increasingly larger and more integral portion of military weapon systems. Paradoxically, the U.S. government, and more specifically the DoD, will continue to have a declining influence over industry

trends. The continuing challenge for the DoD: *Pursue better approaches to capitalize commercial technology advancements and appropriately ensure the health of its defense electronics industry.*

SPECIAL ESSAYS:

The following essays expand on some of the challenges discussed previously. They are study group pieces, with several contributors, and therefore are not attributable to particular authors.

I. Enlisting Small Business in America's Defense: A New Way to Stay New Wave

A Cornerstone of National Security. The United States' military power is crucial to attaining its goals in world affairs. Increasingly, the military relies on high technology electronic equipment to get the job done. In fact, electronics now makes up almost half of the defense procurement, research, and development (R&D) revenue.[39] While electronics spending dominates defense system acquisition costs, the gargantuan commercial electronics sector dwarfs the defense electronic industry. As noted previously, the defense market only makes up less than 1 percent of the market today, falling from its pre-eminent 35 percent position in the 1970s.[40] This plus the global nature of the industry presents many challenges for the US defense electronics producers as they attempt to meet the nations needs.

This essay examines the defense electronics supply chain. It then evaluates the defense electronics industry's capability to produce and sustain a very sophisticated array of equipment needed to survive in a sometimes less than friendly world. Lastly, it offers an innovative concept to insure the defense electronics industry remains viable in its role as a cornerstone of US national security.

A David Amongst the Goliaths. Electronics affect our lives at every turn. Electronic components and technologies are integral in every product and process from talking toys to supermarket checkouts to the digital watches on our wrist. The industry is a behemoth with over $3 trillion in revenue for the Electronic Business 300 alone.[41] It employs 5.3 million people in the US. This is more than the food, chemical, and auto industries combined. High technology merchandise accounts for 29 percent of US exports. At $223 million, electronics is double the dollar value of transportation exports, the next largest segment.[42] These statistics indicate both the importance of the industry to US economic health and the industry's global nature.

Pervasiveness in products, tremendous size, horizontal integration, a weakened investment market along with significant barriers to entry characterizes today's commercial electronics market. The high entry costs, skilled labor requirements, and investor demand for stable cash flows create not only significant barriers to entry, but significant motivations to exit as well. The myriad of telecoms and dotcoms that have gone by the way side recently reflect this. Still numerous goliath-like commercial electronics firms remain, such as IBM, Motorola, and Intel, dwarfing the defense SCD industry and making it a David amongst Goliaths not only in size but in influence as well.

Challenges of Supply Chain Management. Diminishing manufacturing sources (DMS) continue to plague the defense industry and drive up costs. The defense

electronics sector's relative size when compared to the commercial market has created a "Dangerfield Effect," that is "they don't get no respect" from component suppliers. Typically, defense firms need quantities in the thousands while component suppliers are looking to supply millions or more. As such, defense firms just do not have the influence to get responsive action to supply requests and are told to get in line. In most cases, this is the back of the line. This increases lead times for component deliveries. Worse yet, some suppliers have unilaterally quit producing key components with no warning to the manufacturers. This wreaks havoc on defense firms' schedule control and results in higher finished product costs.

As a result, the ability of this sector to surge or mobilize to meet any significant increase in DoD demand may be extremely limited. In order to meet potential future need of the DoD, the fundamental surge and mobilization limitations in the SCD sector need to be identified, and a solution to overcoming the restrictions or bottlenecks to production needs to be found. Otherwise, there may come a day when the DoD will be unable to provide quantities of semiconductor devices for some systems to support a war time need-- for want of a piece of etched silicon.

The Supply Chain and the Government as a Venture Capitalist. The fundamental limitations in the DoD electronics supply chain are; 1) availability of military specific piece parts, 2) availability of clean room space and facilities and 3) availability of production line equipment that can be dedicated to DoD products.

What constrains these "availabilities" of parts and facilities is the absence of production volume sufficient to entice the large manufacturers into the DoD market. Therefore, the solution lies in leveraging those companies who already do small production runs and provide incentives to produce DoD devices. The companies that may fit this requirement are typically "niche" manufacturers; small operators, with limited resources and capital. These companies have their own production capacity problems that must be resolved before they can be linked together to form a sustainable supply chain for DoD program specialized components.

These companies have some common characteristics. They are relatively small, ranging from perhaps 20 to 100 employees. They typically operate on a small margin, and, for those companies that have survived for very long, typically do not carry huge debt loads. Their facilities are small, with limited floor space. Their clean room fabs are also correspondingly small. Often, they buy used (for as little as 10% to 50% of the equipments original cost) or refurbished equipment (or equipment they refurbish themselves) that is one or two generations behind the current state of the art demanded by the "big boys", who require high volume production to pay for their capital investment in the new technology.

Capital investment for new machinery and facilities tends to be problematic for small IC or sensor companies. In some cases, their business strategy requires they buy with cash. Other company's debt limitations are imposed by their parent companies. In any case, the capital investment must be recovered if the company is to stay in business. These issues persist for many tiers in the supply chain, from commercial parts vendors, to original substrate manufacturer, to die producers, to component manufacturers and on up to the finished product. How then can these companies alter their current capacity and set

up (or modify) production lines and facilities to produce a DoD specific product? The answer lies in how the government approaches the problem.

The government typically acquires a system by putting a specification in a Request for Proposal (RFP), looks for contractors to submit bids and selects either the low bidder or, in some cases the best value bid, and signs a contract with the successful bidder. This model does not work for many DoD electronics applications because there just is not enough money to be made to warrant going after the DoD work. In this situation, the government's role needs to change. Instead of *buying* a product, the government should consider investing in a commercial capability to *produce* a DoD product. Like a venture capitalist in the commercial sector, the government would seek out companies with core equities similar to (but perhaps not identical to) what is required to produce the particular DoD item, and invest in that company such that their production facility can serve a dual use, producing both the DoD item as well as the company's commercial items. Where the government investment would differ from the venture capitalist though, is that unlike a venture capitalist, who wants a return on his investment in the form of profits on sales, the government as an investor now wants priority on the production line. By investing in a few companies along the entire supply chain (companies selected through extensive market research), the government can now have a vested interest in what is produced by that chain. Additionally, if the *quid pro quo* for the small company is that the contractor can use that line for other commercial products, then the line stays operating while waiting for the next DoD product and the contractor has the incentive to stay with the business.

An Entrepreneurial Government : A New Way for a New Day. How, then, does the government enter into such an arrangement with small businesses? To some extent, federal acquisition regulations limit what the government can do to partner with any specific company, particularly if it can be perceived that the government is providing (or has provided) preferential treatment (and hence an unfair competitive advantage) to one company over another. But the market in which DoD must now acquire what it needs has changed, and with no bidders (or worse, with burdensome contract vehicles that result in potentially non-responsive bids), it is time the federal government allowed agencies with special production requirements to form close relationships and partnerships with industry in new and different ways. This does not mean putting the large defense contractors in the driver's seat and having the government serve merely as a funding "fire hose". Rather, the partnerships required here are ones that foster growth and sustainability in electronic niche areas largely ignored by big companies. This is the world of the small business, and it is a world that is ripe for government investment. Currently, there are a few DoD funding vehicles that allow special arrangements with small businesses, a summary of a few of them is provided as an endnote.[43] But funding is not the only issue. Two additional barriers to small companies entering into DoD work are; 1) the morass of acquisition requirements levied by a plethora of federal acquisition regulations and 2) security requirements for conducting classified work. To remove (or at least lower) these barriers, processes must be streamlined for efficient use by the small business. In establishing a relationship with smaller companies, communication of expectations and requirements on both sides must be clear and the government must display a willingness (and capacity) to adapt to the small business environment (vice

adapting the small business to the government environment). Careful analyses of the market, of the individual companies, of the technologies being used and the production processes being established are required for success. In short, if the DoD is to use small business to develop a sturdy and reliable supply chain for critical items in the electronics sector, the DoD must become educated and think like a small business but be ready to provide the investment capital like a big business.

Small Business to the Rescue. The fact that the large businesses are unwilling to take on the limited production runs required for DoD specialized electronics components should be a wake-up call for the Department of Defense. The continued consolidation of the defense industrial base in a "acquire or be acquired" fashion only makes these large defense contractors more like their commercial brethren. To 1) overcome critical shortages and hence long lead times of relatively simple military specific parts, 2) provide sufficient component production capacity to support current DoD needs for both legacy and new systems, and 3) provide a surge capacity for future requirements, the DoD must invest to some degree in every link of the product's supply chain. Special emphasis and investment must be applied to those portions of the supply chain that are most constrained. The DoD must provide whatever incentives are necessary, sufficient and affordable to members of the supply chain to ensure their participation.

Incentives in the form of capital investment will only be effective if the companies in the chain have the flexibility, adaptability and innovative mindset to accommodate the DoD products while still maintaining the company's core equities. Interviews with some players in this arena suggest there are small businesses out there in the civilian sector willing to take on these tasks, but they need help. Not only do they need the investment capital, but they also need the long-term commitment that only a good partnering relationship can bring. Arguably, the real strength of the United States economy lies in the innovative and tenacious nature of American small businesses. Only through leveraging small businesses in partnership with the government will the DoD be able to affect the niche market that electronics for military systems has become in this globalized age of large industrial conglomerates.

II. A New Paradigm for Research and Development.

Introduction. U.S. economic growth requires international competitiveness, which in turn requires new technology. New technology requires significant investment in research and development. Research and development (R&D) is widely recognized as a key driver of economic growth. The roles played by the federal government and the U.S. private sector in the funding of R&D has changed dramatically. In 1980, private industry replaced the federal government as the primary source of R&D funding. Between 1990 and 1997, federal R&D funding declined 26 percent relative to GDP. Although corporate R&D funding has soared, particularly among high-tech firms, it is often focused on near-term product development. The erosion of support for basic research, both federal and corporate, over the long term will have a negative impact on U.S. economic growth.

Investments. A sustained public investment in long-term basic research provided the foundation for today's U.S. scientific and technological leadership. Specifically, federal support for R&D has contributed to the development of the Internet, personal computers, the silicon chip, the laser, fiber optics, supercomputers, and many other technologies. These innovations have grown into industries that now employ over 4.8 million American workers with average salaries that are 77 percent higher than the average private sector wage, according to an American Electronic Association's (AEA) report.

The resources invested in R&D in the United States have risen over the past few years, from a period of stagnation through a period of unprecedented growth, closely following the overall growth of the economy. The continued growth of R&D commitment was largely the result of the industry’s awareness that continued investment in R&D is necessary for long-term survival.

High-tech firms are spending $40 billion annually on research and development. That represents 37 percent of the $109 billion in industry-funded R&D in 1995. Industry segments leading the way in research spending are electronic components manufacturing and computer and communications services. Five of the top 10 U.S. companies in R&D spending are from the high-tech sector: IBM Corp., Hewlett-Packard Co., Motorola Inc., Lucent Technologies and Intel Corp.

The U.S. electronics industry, driven with revolutionary development of information technology, generated approximately 1.2 million jobs and $300 billion in U.S. revenues in 1998. To keep the leading position in a global world, the U.S. electronics industry must continue to invest heavily in R&D. In 2000, the U.S. semiconductor industry invested 14% of total revenue in R&D, a higher percentage than any other American industry and three times the industrial average.

Integrated Circuit Process Innovation. The fundamental integrated circuit (IC) building block is the complementary metal oxide semiconductor or CMOS gate transistor etched into a substrate of pure silicon or chip, a technology first invented in 1933 but not developed until 1963.[44] The CMOS transistor technology is attractive because of relatively low power dissipation characteristics and the abundantly available raw material. For many generations of IC development, the physical property constraints of CMOS transistor architecture on pure silicon substrates remained negligible. The decision to rollout new advancements in standard transistor size or speed of operation involved a tradeoff between cost to manufacture and benefit of the technologies applied to a direct scaling of size. Unfortunately, the ability to apply innovative technology solutions to continue the direct scaling of CMOS semiconductor IC’s must have an end at some point. New technological solutions will require different substrate material composition beyond pure silicon. Even with new materials, molecular structure limits the ultimate physical size of CMOS transistor IC designs.

A recurring barrier to continuing IC transistor miniaturization is the photo-optical lithography process. Lithography involves complex exposure equipment; photo-resist material and processing equipment; mask making material and equipment; and metrology equipment for dimension measurement, overlay control, and inspection processes. The current state-of-the-art lithography equipment uses 248-nanometer wavelength light to

develop IC masks with transistor gate lengths as small as 100-nanometers. However, the spacing between the transistors can be no closer than the lithographic light wavelength. [45]

Enhanced future optical lithography capability will support fabrication needs until IC architectures reach 65-nanometer size. New developments in resolution enhancement using techniques such as off-axis illumination (OAI), phase shifting masks (PSM) and optical proximity correction (OPC) must mature to meet these requirements. In addition, reducing transistor spacing requires perfecting reduced lithography wavelength equipment using 193-nanometer first, then 157-nanometer equipment. [46]

The optical lithography process will not support manufacturing architectures of 45-nanometers and smaller. Next generation lithographic (NGL) processes must be developed and matured to continue the miniaturization roadmap. The most promising new technologies include extreme ultraviolet lithography (EUV) and electron projection lithography (EPL).

Silicon Materials. For the past 30 years, traditional transistor scaling techniques have achieved all IC miniaturization advances on the base silicon substrate. Extending the fundamental size limit for CMOS transistors based on silicon will require introduction of new materials to continue the miniaturization path. Several technologies offer promising solutions to the material problem such as silicon-on-insulator (SOI), silicon-germanium (SiGe), and several double gate technologies including vertical transistor and FinFET designs.

Silicon-on-insulator (SOI) refers to placing a thin layer of silicon on top of an insulator such as silicon oxide or glass. Ultra-thin body transistors are structured on this thin layer of silicon. A projection for scaling with this technology yields 22-nanometer gate length transistors by 2016. Further development of the technique is required before ultra-thin body SOI technique matures to full potential.

Introducing germanium into the basic silicon structure to create a new alloy of silicon-germanium (SiGe) allows enhanced electron (or hole) flow mobility and significantly improves transistor operation. Silicon-germanium transistors are capable of much higher speeds than silicon only transistors. Using a technique called band-engineered transistors on a silicon or SOI substrate allows manufactures to take advantage of the enhanced SiGe characteristics for IC's. An enhanced-mobility channel SiGe process is under development.

The double gate transistor is another technology promising to overcome the shortfalls of typical planar silicon (CMOS) architectures. The basic double gate design builds transistors with two horizontal surfaces, having current flow paths in the horizontal direction. Vertical transistors are an extension of double gate technology with two vertical surfaces and vertical current flow. The vertical double gate transistors use oxide growth techniques to precise film thickness independent of lithography with device gate lengths as small as 50-nanometers. [47] High performance transistors with gate length as small as 18-nanometer have been built with a technique using a self-aligned double gate metal oxide silicon field effect (MOSFET) architecture structure called FinFET. [48] All of these techniques show promise but are still in the research and development stage.

New Materials. Research institutions and industry are presently investing heavily into materials technologies that could one day replace silicon as the fundamental

semiconductor building block. For example, IBM will spend up to $300 million between 2000 and 2005 exploring molecular and quantum computers.[49]

Today's front-runner was a curiosity when discovered at Rice University in 1986. Dr. Richard Smalley and a team of researchers vaporized carbon atoms and allowed them to cool in an inert gas. Carbon, like silicon, has well understood and extensively studied properties and is a readily available inexpensive element. Carbon nanotubes, or carbon tubes of single atom thickness, were initially studied as an alternative to conventional load bearing structures. In composite form, aircraft structural elements as well as recreational equipment such as the tennis racket, take advantage of the strength of carbon fibers.

Since their introduction, research for processing techniques for carbon-based molecular structures has yielded AND/NOR gates, switches and conductive connections. To date the biggest obstacle for producing molecular sized microcircuits is assembling the constituent components into a workable microcircuit. Scientists at Lucent Technologies have successfully fabricated a single molecule, individually addressable transistor. Using hybrid techniques of silicon wafers and carbon nanotubes, Lucent's team is pursuing fabrication techniques that could usher in the era of molecular computing.[50]

Using hybrid silicon and carbon nanotube circuitry, Dr James M. Tour is studying development techniques for producing chips that incorporate carbon nanotubes that will not be much smaller than today's microcircuits, but that can be produced cheaper than they are today because production will not require the expensive clean rooms used in present state of the art chip manufacturing.[51] Dr Tour expects his techniques will be adopted by the industry within the next three years. This approach to manufacturing hybrid chips is also being pursued at Harvard University. A team of chemistry professors is working on producing chips with nanocircuits that do not require the specialized clean rooms of conventional chip manufacturing facilities. While the hybrid chips will have more defects due to contamination by dust, the redundancy of circuitry will allow mitigation of these defects by software workarounds.[52] While this may be a sign that technical advancements are in an early stage of research and development, it may also signal each firm's desire to achieve a competitive advantage over its competition by maintaining tight control of production techniques.

Clearly, the technological frontier promises a rewarding and mind-boggling harvest— it merely awaits being tilled. A new paradigm for R&D expenditures is required wherein the U.S. Government must be the primary source of investment capital to encourage the basic research that, when commercialized, keeps the U.S. on the technological leading edge.

III. The Problems of Human Capital.

During the past several decades, the United States high tech electronics industry has set a standard for competitiveness. Due to its well-known reputation for rapid innovation and technical prowess, the industry rates special scrutiny as a leading economic indicator. The electronics industry is a unique sector because its success or failure trickles over to virtually all other industries that benefit from the progressiveness and productivity of the goods and services it provides.

There has been an increase in high-tech industry employment with a robust doubling of jobs in the high-tech software and computer services sectors followed by an aggressive 30% increase in communication services. In electronics manufacturing, we still see a combined 7% employment increase among the manufacturing sub-sectors even though we now outsource much of our manufacturing requirements to factories around the globe.[53]

Nonetheless, electronics firms are experiencing difficulty in their ability to hire skilled labor. The major reason is the growing use of technology in all business areas, which has increased horizontal job opportunity. Demographically, population age is also having an impact as we have passed the peak of the baby boom generation and smaller numbers of high school graduates are entering college. As the leading cusp of the baby boom generation retires, companies are left with fewer experienced people, prompting predictions that the shortage will continue.

As technology in the electronics industry becomes more skill-dependent, college coursework is becoming more specialized and the ability to stay proficient more challenging. This leads potential students to consider careers that use computers, but not to pursue heavy mathematics or engineering loads. Although there has been an explosion in computer literacy, many students still view the computer field as a less-than-glamorous career choice.[54]

The electronics industry is turning to innovative ways to attract qualified industry experts from a shrinking pool of available talent. Traditional recruiting approaches such as job fairs, newspaper ads and visits to college campuses continue, but personnel departments are increasing their use of the Internet and other aggressive, new methods to make their firms stand out in this very competitive field. Technical professionals are benefiting from improved benefit packages, higher salaries and additional workplace flexibility. The downside for these employees is that many of them are being asked to work extended hours to fight the shortage of qualified workers.

The extremely tight job market has also forced firms to address quality of life concerns previously thought unimportant. Casual attire, paid sabbaticals and flexible working hours are examples of accommodations that companies are making to improve the work environment for employees.[55]

To appeal to the best and brightest, some companies have established in house think tanks. Within these teams, innovative specialists are able to discuss new ideas that the company may be willing to fund, assuming their ideas meet reasonable business criteria. Successful individuals who carry ideas through development share in financial rewards, much like they would if they were working for a smaller progressive dot com.

Many high tech firms use stock options to recruit and retain highly skilled employees. Besides the tax benefits for corporations and employees, stock options reduce company payrolls while giving employees a stake in the success of the corporation. Though successful as the tool in the 1990's, these plans are having less of an impact now in view of the recent decline in the stock market. Lockheed Martin's recruiters emphasize the advantage of working for a large corporation and not just the diversity of work the company has to offer. Other large corporations are quick to point out that there are not many new companies offering competitive 401(k) and non-contributory pension plans. They also add that very few people working for Internet

companies become millionaires. Indeed, about 75% of all Internet companies will never make money.[56]

Some companies are attracting and retaining employees by allowing employees use of company assets and other perquisites. Boats, planes, limousines, vacation property, box seats at sporting events, and company-owned housing are part of the recruiting tool box.

Employers are also using cash to attract engineers and scientists. Some companies are paying people just to apply. Many companies are paying up to $300 just for quality resumes. They then close hiring deals with a signing bonus. As the demand for critical skills in the electronics industry continues to rise, it is likely that hiring budgets will have to increase with them to stay competitive.

Many medium-sized electronics companies are benefiting from the recruiting slowdown that has caused large corporations to downsize and many “dot-coms” to close shop altogether. These companies are able to attract engineers by offering rewarding work; this is, work that engineers enjoy. The recruiting challenge is to make the job sound interesting. Selling the working environment as a distinct advantage, emphasizing the division of labor and organizing work in a fashion that is rewarding will often accomplish that task. However, these managers also recognize the need to match pay scales with the industry giants.[57]

Beyond the efforts that companies are making to attract and retain critical talent, it is worthwhile to consider the primary source from which the U.S. develops this talent, for the efforts discussed above primarily involve efforts to attract talent from a relatively small pool rather than efforts to actually enlarge the supply of talent. Education and training play a vital role in producing skilled workers needed by high tech industry. The electronics industry has a very high demand for high school and University graduates with high degrees of competency in science, math, engineering and technology (SMET), to stay ahead in creating new products and services. To the nation’s credit, achievement scores in math have improved over the past decade.[58]

The issue of acquiring and attaining skilled knowledge workers as changed from a national issue to a global one. The U.S. is now faced with not only retaining U.S. workers but in obtaining workers (and retaining) knowledge workers from over-seas. One important approach is the tailoring of immigration policy to welcome skilled high-tech workers from abroad. This is a two-way street—the other side being the possible negative impact of losing good technical people to other countries. International competition for skilled workers will only increase as the knowledge economy expands.[59]

The success of the industry is closely dependent on our nation’s ability to grow the human capital it needs to stay on the leading edge. Productivity in the electronics industry is growing at a fast pace. While our school systems are struggling to keep up with change, they need additional resources to meet future industrial expectations. Until our schools can catch up, we must support industry efforts to import talent from around the globe. By supporting industry efforts to transform education and attract the necessary talent, we will ensure ourselves a renewable world-class workforce that has no peer, continue to dominate in the global technology arena and bring unprecedented prosperity to our nation for decades to come.

In managing a technology-driven company in the 21st century, the ability to meet growth objectives is most likely constrained by the ability (or inability) to find the right

technical people. A majority of technology companies are suffering from a talent shortage, the cost of which is a bottom line issue that affects both today's business performance and the ability to pursue tomorrow's opportunities.[60] While the current economic downturn has temporarily mitigated this challenge, it is formidable and will always be there in the long-run.

Endnotes:

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[2] U.S. Bureau of Labor Statistics from "Digital Economy 2000", Economics and Statistics Administration, U.S. Department of Commerce, Washington D.C. 20230 <http://www.esa.doc.gov>

[3] Many of the companies surveyed for this study agreed that unless very high ROIs were achievable, capital investments would not be made as the risks would not be commensurate with the gains. The typical ROI provided by these companies was 60%. A summary of these ROI requirements are discussed in both the "SIA SEMICONDUCTOR FORECAST, 2001-2004" and "The Evolution of Fabless and its Impact on the Semiconductor Industry."

[4] Noted by Gordon Moore, cofounder of Intel Corporation in 1965, this doubling effect means that chip density is increasing by a factor of 10 every five years, and by a factor of 100 every ten years. See the Intel Museum Home Page, <http://www.intel.com/research/silicon/mooreslaw.htm>

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[15] John McHale, "Obsolescence: The Dark Little Secret of COTS", *Military & Aerospace Electronics*, vol. 10, no. 2, February 1999, page 13.

[16] During the development of some field radio systems, because numbers required were too small, parts suppliers refused to provide items. Therefore, to meet schedule, these programs purchased commercial cell phones and scavenged the "onesy/twosy" items necessary to support their product.

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[43] Alternative sources of funding for process innovation:

1. Cost Reduction and Effectiveness Improvement (CR&EI) Initiative (also known as the Corporate Productivity Fund (CPF): The purpose of this program is to identify and fund cost savings/avoidance initiatives for which a relatively small injection of funds yields substantial cost savings/avoidance. The fund provides Program Managers the opportunity to bring forward cost reduction investment opportunities for which funding is otherwise not available.

2. Manufacturing Technology (MANTECH): MANTECH is a DoD sponsored program. The purpose is industrial preparedness aimed at helping industry implement advanced manufacturing processes or equipment in support of requirements identified by acquisition program offices or life cycle support activities. Specific program thrusts include: 1) Processing and Fabrication, 2) Advanced Manufacturing Enterprise, 3) Energetics/Munitions, 4) Sustainment and Readiness. WEB Site: www.dodmantech.com

3. Commercial Operations and Support Savings Initiative (COSSI**)**: COSSI is a joint services sponsored program. The purpose is to provide funding for the non-recurring engineering, testing, and qualification needed to insert a commercial technology into a military legacy system to reduce operations and support costs. Note that COSSI requires a joint proposal from a Government/Contractor team, with a

minimum 75%/25% cost share with two phases: Phase I: Proof of concept, Phase II: Production (non-competitive), WEB SITE: www.acq.osd.mil/es/dut/cossi

4. Dual Use Science and Technology Program (DU&ST): DU&ST is a joint services sponsored program. The purpose is to partner with industry to jointly fund the development of dual use technologies needed to maintain our technological superiority and for industry to remain competitive in the marketplace. There is a 50/50 cost share between DoD and Industry. There are specific focus areas for each service during each fiscal year. These focus areas are listed on the web site. However, it also states in the instructions that new topics may be added. WEB SITE: www.dtic.mil

5. Small Business Innovative Research (SBIR) Program: The SBIR program is meant to stimulate technological innovation by small businesses and increase the commercial application of federally supported research results. WEB Sites: www.acq.osd.mil/sadbu/sbir, www.dtic.mil/dtic/sbir

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